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COMPLETE SPECIFICATION.

Improvements in and relating to Fine Focus X-ray Tubes.

I, VERNON ELLIS COSSLETT, of 1 Long Road, Cambridge, England, a British Subject, do hereby declare the invention, for which I pray that a patent may be granted to me, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to X-ray tubes and in particular to X-ray tubes producing a fine focal spot suitable for use in X-ray shadow microscopy. The fine focal spot may approximate to a point source of X-rays or it may constitute a line source of minute width and controlled length.

Hitherto X-ray sources of the order of 40 microns in diameter have been achieved, but the invention has for its object to enable much smaller sources of the order of 1 micron or less to be obtained. The lengthy investigations which have resulted in the present invention have established that special adjustability of the means for focusing the electron beam on the target and a special target construction are essential to enable the desired result to be produced.

According to the invention the target surface which constitutes part of the wall of the evacuated envelope of the tube and also serves as a window for the passage of the X-rays generated by the electron beam incident on the target, is carried by a tubular neck which passes through the field space of a magnetic electron lens which is external to the evacuated envelope, and provision is made for relative adjustment between X-ray tube and electron lens in such manner that the magnetic axis is parallel with the axis of the electron beam within the tubular neck, is coincident therewith at the target surface, and the target surface coincides with the area of least cross-section produced in the electron beam by the magnetic lens.

Reference will now be had to the accompanying drawings in which:—

Figure 1 is a diagrammatic representation of an X-ray tube according to the invention.

Figure 2 is a diagram of an alternative detail.

Figure 3 is an enlarged view of the target end of the X-ray tube of Figure 1, showing also the association of the tube with auxiliary equipment for use in X-ray shadow microscopy.

Referring first to Figure 1, the electron gun is a triode structure consisting of a filament 1, a shield 2 and an anode 3. For convenience in handling the tube, the anode 3 and the body of the apparatus are at earth potential, the accelerating voltage is obtained by applying a negative voltage to the filament 1, and the shield is further biased negatively with respect to filament 1. The electron gun structure is connected to the remainder of the X-ray tube by means of a bellows 4 to facilitate the alignment of the electron beam.

In the construction shown the electron beam passes through a first electron lens 5 constituting a condenser lens. This is a magnetic lens without pole pieces. Its presence is necessary if a particularly small focal spot is required at the target surface, although for some purposes it can be dispensed with. Beyond the electron lens 5 the tube body 6 is provided with a connection 7 to the pumps for evacuating the tube. The construction shown is of a demountable character which introduces the necessity for pumping. The invention can however equally be applied to a permanently sealed-off tube.

At the end of the tube remote from the electron gun is a platform 8 which supports the X-ray target and also the magnetic electron lens for concentrating the electron beam on the target. Standing on the platform 8 externally of the tube is a tripod support 9 to which is affixed a table 10 on

[*Price* 3s 0d] 4s 6d

Price 25p

which the objective lens 11 is adjustable. In the drawing the adjustment from left to right is effected by means of screws 12 associated with the table 10. Adjustment in the plane of the table 10 at right angles to the direction of the screws 12 is effected by a similar set of adjusting screws (not shown). By means of the tripod with its adjustable legs, the table 10 can be tilted in relation to the axis of the electron beam from the electron gun and if desired the axial distance from the gun can also be adjusted. The axial alignment of the magnetic axis of the lens 11 with the axis of the electron beam is performed by means of the adjusting screws 12 associated with the table 10.

The actual target of the X-ray tube is constituted by a lamina 17 which also forms the window by means of which the X-ray beam emerges from the tube. This window 17 is carried at the end of a vacuum liner 15 which is attached to the tube body 6 by means of a bellows 13. The base 14 of the liner 15 extends laterally beyond the bellows 13 and is threaded for engagement with an adjusting ring 18 which enables the axial position of the liner in relation to the magnetic lens 11 to be adjusted. The body of the liner 15 terminates in a neck 16 which passes between the pole pieces 19 of the lens 11 and carries the window 17 at its end.

When the necessary axial alignment of the magnetic lens 11 with the electron beam has been effected by means of the adjustment of the tripod 9 and the adjusting screws 12, the point of minimum cross section of the electron beam resulting from the effect of the lens 11 can be brought into coincidence with the window 17 by means of the adjusting ring 18. Alternatively instead of adjusting the position of the window 17 in relation to the lens 11 the lens 11 could be movable in the axial direction for this purpose or alternatively the pole pieces 19 could be adjustable axially in relation to the lens 11.

When employing both a condenser lens 5 and an objective lens 11 as shown in Figure 1 it is necessary to have complete freedom of adjustment of the lens 11 so as to obtain as small a source of X-rays as possible. If however the lens 5 is dispensed with, a simpler adjustment is possible by substituting for the independent adjustment by tripod and by centring screws 12, an arrangement as shown in Figure 2 in which the lens 11 is supported on a fixed spherical surface 20 which is concentric with the filament 1. Interposed between the lens 11 and the table 20 is a mount 21 which is secured to the lens 11 and has a curvature complementary to the spherical table 20. By means of two sets of adjusting screws 12 (only one set being shown) the lens 11 is adjusted in position on the table 20, the lateral displacement being associated with a corresponding tilting movement due to the spherical curvature, with the result that the radial relationship between the axis of the lens 11 and the filament 1 is maintained.

Further details of the construction of the target end of the X-ray tube of Figure 1 are shown in Figure 3. This construction is particularly applicable to demountable tubes. The metal foil 17 constituting the window of the tube is clamped in position against the end face of the neck 16 by means of a clamping ring 23 but with the interposition of an apertured soft metal washer 22 which not only serves to form a vacuum seal but also ensures good metallic contact. Indium or lead is suitable for the washer 22. The clamping ring 23 is urged against the soft metal washer 22 by means of a thrust sleeve 24 which is inserted within the neck 16 and is urged into position by means of a screw-ring 25 in engagement with a screw thread at the lower end of the neck 16. Owing to the small dimensions of the apparatus, the overall diameter of the sleeve 16 being 6 mm. and the opening in the end face of the neck and in the ring 23 being $\frac{1}{2}$ mm. in an actual tube constructed in accordance with Figures 1 and 3, it is necessary to provide means remote from the end of the neck 16 for clamping the window 17.

The window 17 is a metal foil consisting of the metal which is appropriate for the X-rays it is desired to generate. From practical considerations foils of tungsten, gold, copper, silver, molybdenum are suitable. The thickness of the foil should be of the same order of magnitude as the size of the X-ray spot to be formed, i.e. approximately 1 micron for shadow microscopy purposes. The size of the central aperture in the clamping ring 23 is determined by the need to provide a stop to limit the spherical aberration of the lens. The opening in the end surface of the neck 16 against which the window 17 is clamped should be as small as possible in order to minimize the load on the foil due to the pressure difference on the two sides. In practice it is convenient to have this aperture the same size as that in the clamping ring 23

In the interests of clarity the clamping ring 23, the soft metal washer 22, the window 17 and the end of the neck 16 have been shown in spaced relationship in Figure 3. In practice they are of course clamped tightly together to form a very compact and solid end giving good mechanical strength and heat transfer properties.

Figure 3 also shows the association of an X-ray tube according to the invention with auxiliary equipment for use in X-ray shadow microscopy. The X-ray tube is capable of giving an intense and exceedingly small focal spot of the order of 1 micron or less in diameter, and thus provides what can be regarded as a point source of X-rays. The

specimen to be examined is mounted on a support 26 outside the tube but in the proximity of the target-window 17. The specimen support 26 is carried by a tube 27 which is adjustable on a ring 28 so that the distance from window to specimen can be adjusted. Centring screws 29 (only one pair being shown) enable the ring 28 to be moved in a plane parallel to the window 17 for the purpose of centring the specimen with respect to the X-ray beam. The X-ray shadowgraph is recorded on a photographic plate 30. The magnification of the shadowgraph is determined by the geometry of the system and no limitations are imposed by the grain of the photographic plate. The construction of the tube permits the specimen to be brought very close to the target-window, thus giving high geometrical magnification. Stereography can be carried out very simply in this apparatus. All the specimen is in focus at once with the same resolution, as given by the spot size, although different planes are magnified by different amounts. Three-dimensional imaging can thus be obtained by taking two photographs from slightly different viewpoints; as divergent illumination is employed, the specimen may either be tilted or translated between exposures. The resulting stereographic pairs may be mounted to show directly the spatial configuration of the specimen in a way which is not possible in optical microscopy, owing to the limited depth of focus at high resolution.

What I claim is:—

1. An X-ray tube wherein the target surface, which constitutes part of the wall of the evacuated envelope of the tube and also serves as a window for the passage of the X-rays generated by the electron beam incident on the target, is carried by a tubular neck which passes through the field space of a magnetic electron lens which is external to the evacuated envelope, and provision is made for relative adjustment between X-ray tube and electron lens in such manner that the magnetic axis is parallel with the axis of the electron beam within the tubular neck, is coincident therewith at the target surface, and the target surface coincides with the area of least cross-section produced in the electron beam by the magnetic lens.

2. An X-ray tube as claimed in Claim 1 wherein the electron lens is adjustable in three dimensions with respect to the tube.

3. An X-ray tube as claimed in Claim 1 or 2, in which the target surface is constituted by a metal foil which except for the window area is in intimate metallic contact with a mass of metal surrounding the window area and providing a stop limiting the aberration of the magnetic lens in addition to ensuring good heat dissipation from the target area.

4. An X-ray tube as claimed in Claim 1, 2 or 3, constructed and arranged substantially as described with reference to Figures 1 and 3.

5. An X-ray shadow microscope comprising an X-ray tube as claimed in Claim 1, 2 3 or 4 in conjunction with a specimen holder adapted to hold a specimen externally of the tube in the vicinity of the target-window, and means for recording the X-ray shadowgraph of the specimen.

V. E. COSSLETT.

PROVISIONAL SPECIFICATION.

Improvements in and relating to Fine Focus X-ray Tubes.

I, VERNON ELLIS COSSLETT, 1 Long Road, Cambridge (British), do hereby declare this invention to be described in the following statement:—

The invention relates to improvements in X-ray tubes and in particular to X-ray tubes producing a fine focal spot. A combination of electron lenses with a special type of target is employed to obtain a very small focus of X-rays and to make available for use the full intensity of X-rays generated. The construction of the invention is made clear by the Figure of the accompanying drawing.

One or more electron lenses L_1, L_2, placed along the path of a beam of electrons issuing from a cathode F of normal type and passing through an anode A, produce a very small spot of electrons on the target T. In principle one lens is sufficient but in practice two electron lenses are necessary in order to give full control of the electron beam. The lenses may be either electrostatic or magnetic in nature, and may be situated either within or without the X-ray tube. In the Figure a construction is shown that employs two magnetic lenses wholly outside the tube. Provision is made for mutually aligning the several parts of the invention. Suitable apertures are placed within the tube.

The target T is in the form of a thin foil or lamina of metal fixed across the path of the electron beam in such a manner that it forms part of the wall of the tube, separating the evacuated space within from the atmosphere without. The target is supported on a metal disc having a small aperture (for example, 0.25 mm.) at its centre. The target may or may not be subjected to forced cooling. The

issuing X-rays may be employed in any manner in which X-rays have hitherto been employed. The object to be irradiated by them can be placed practically in contact with the outside of the laminar target, so that full use is made of the smallness and intensity of the X-ray source.

The lens L_1 is of comparatively long focal length (for example, 1 to 10 cm.). The lens L_2 is of short focal length (for example, 1 to 5 mm.). When of magnetic construction the lenses will each comprise a winding of copper wire, suitably surrounded by an iron jacket; for example, L_1 may have 3600 turns of wire and L_2 may have 20,000 turns. Such a two lens system will provide an X-ray source smaller than 1 micron (one thousandth part of a millimetre) in diameter. The target may be of any metal used for X-ray targets (for example, tungsten). The voltage applied between cathode F and anode A may be of any value, according to the wavelength of X-rays required to be generated for a particular purpose; for example, 10 kilovolts for microradiography of insects or 100 kilovolts for metallurgical investigations.

V. E. COSSLETT.

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from which copies may be obtained.

735,943 PROVISIONAL SPECIFICATION
1 SHEET
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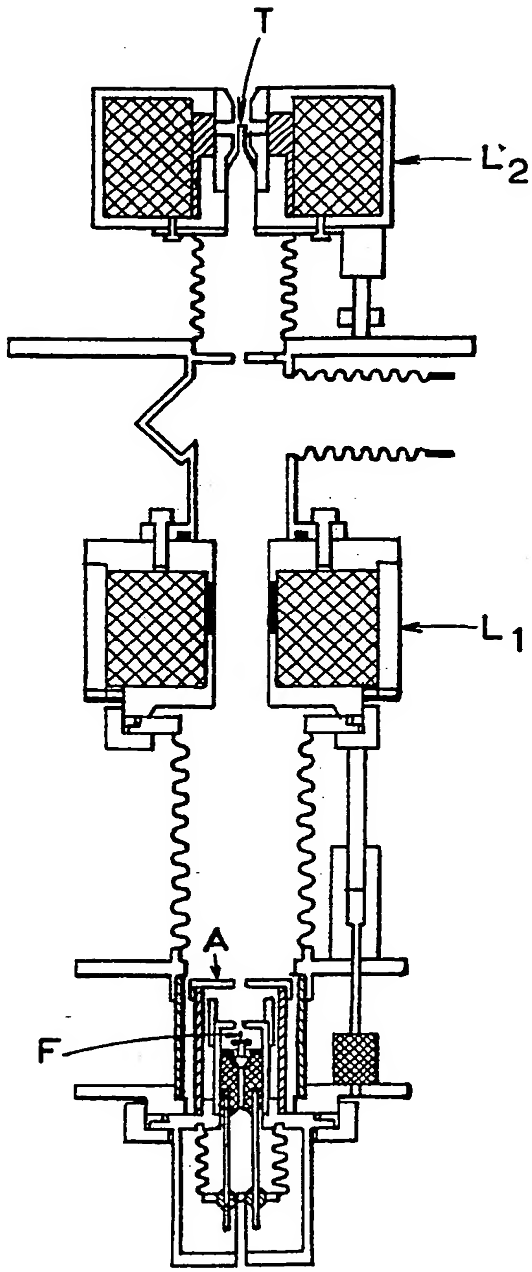

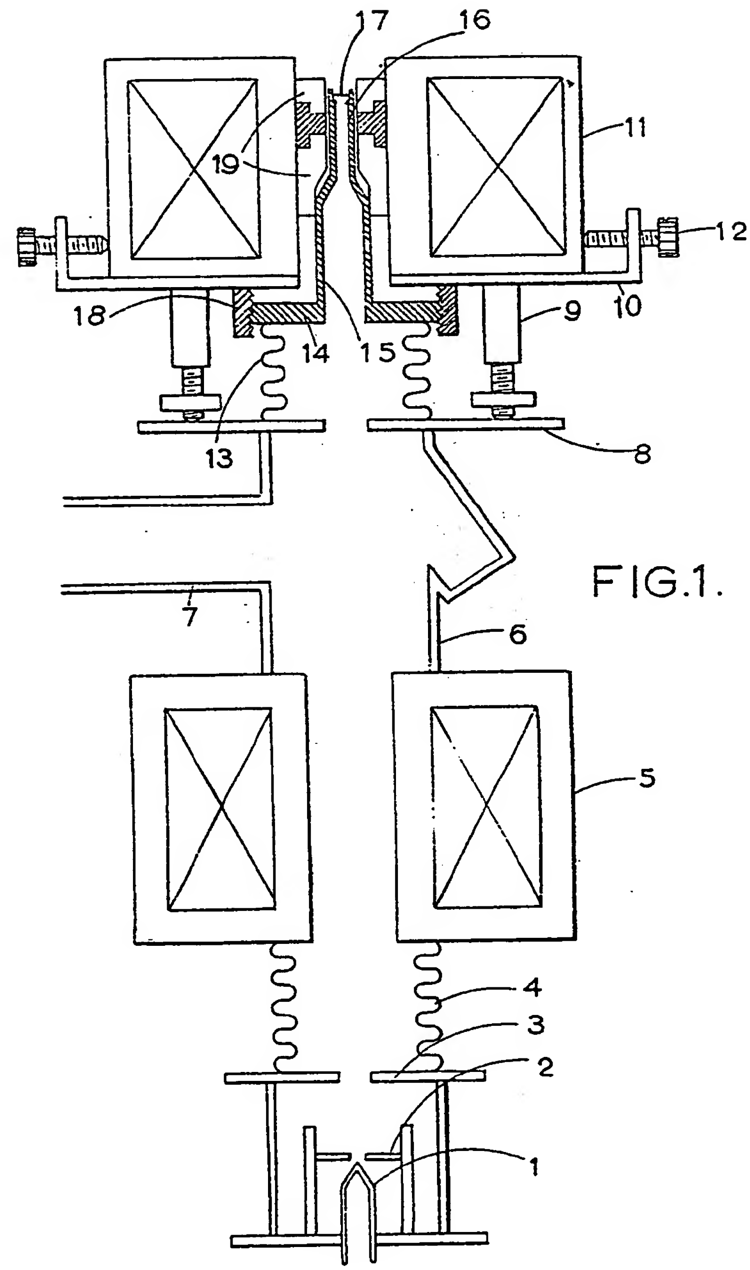

FIG.1.

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SHEETS 1 & 2

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FIG. 2.

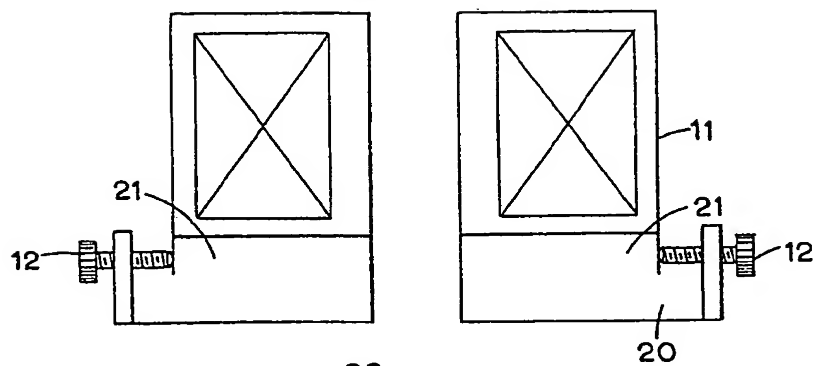

FIG. 3.

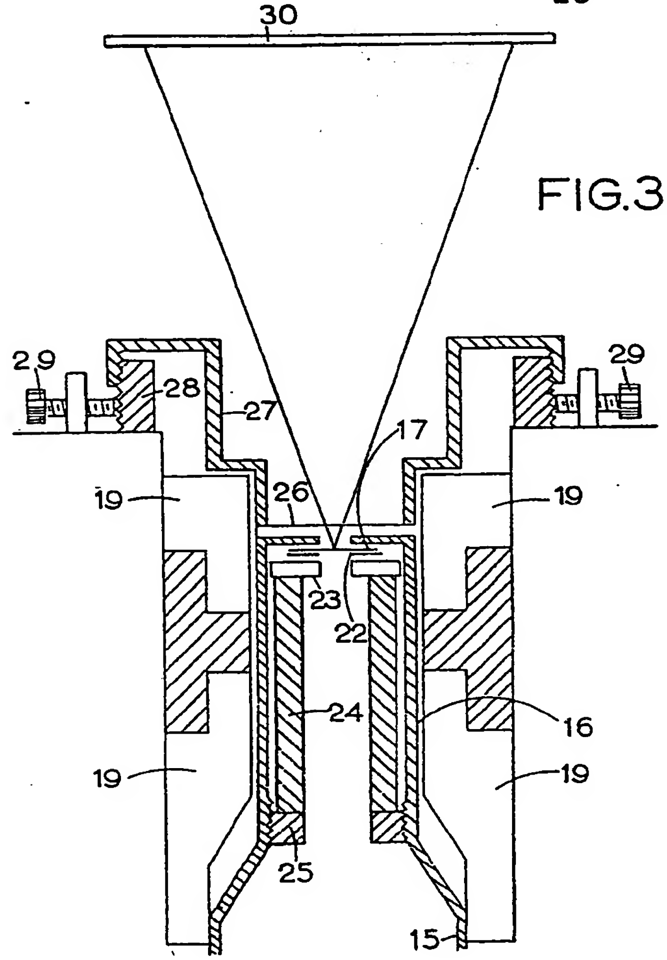

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FIG.1.

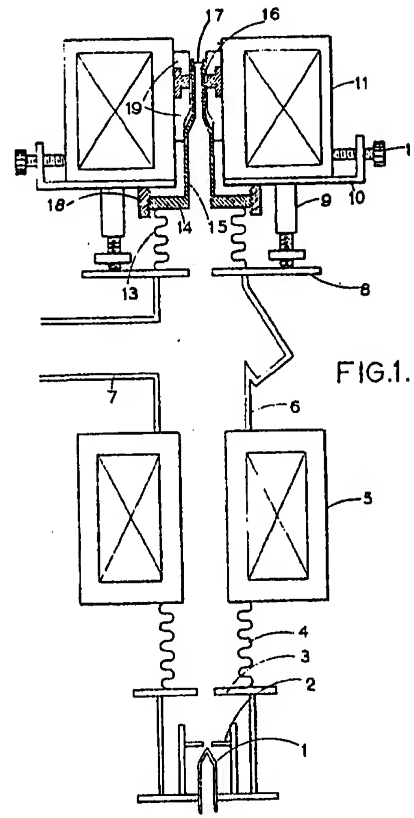

FIG.2.

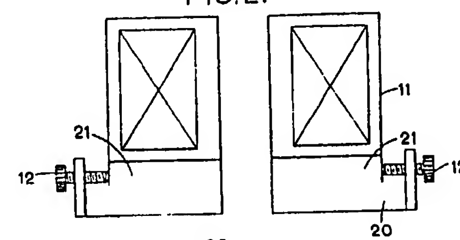

FIG.3.